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Original Contribution

Newly Reported Respiratory Symptoms and Conditions Among Military Personnel Deployed to Iraq and Afghanistan: A Prospective Population-based Study

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Concerns about respiratory conditions have surfaced among persons deployed to Iraq and Afghanistan. Data on 46,077 Millennium Cohort Study participants who completed baseline (July 2001–June 2003) and follow-up (June 2004–February 2006) questionnaires were used to investigate 1) respiratory symptoms (persistent or recurring cough or shortness of breath), 2) chronic bronchitis or emphysema, and 3) asthma. Deployers had a higher rate of newly reported respiratory symptoms than nondeployers (14% vs. 10%), while similar rates of chronic bronchitis or emphysema (1% vs. 1%) and asthma (1% vs. 1%) were observed. Deployment was associated with respiratory symptoms in both Army (adjusted odds ratio = 1.73, 95% confidence interval: 1.57, 1.91) and Marine Corps (adjusted odds ratio = 1.49, 95% confidence interval: 1.06, 2.08) personnel, independently of smoking status. Deployment length was linearly associated with increased symptom reporting in Army personnel ($P < 0.0001$). Among deployers, elevated odds of symptoms were associated with land-based deployment as compared with sea-based deployment. Although respiratory symptoms were associated with deployment, inconsistency in risk with cumulative exposure time suggests that specific exposures rather than deployment in general are determinants of postdeployment respiratory illness. Significant associations seen with land-based deployment also imply that exposures related to ground combat may be important.

longitudinal studies; lung diseases; military personnel; signs and symptoms, respiratory

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval.

Increased reports of respiratory conditions in service members following military deployment to the Persian Gulf region have been documented (1–8). Several studies have attributed the observed increase to deployment-related exposures such as poor ambient air quality (3–6, 9, 10). Geographic areas occupied by 1991 Gulf War veterans were characterized by elevated levels of respirable particulate matter 10 μm or less in diameter and included silica-containing sand (3, 6, 11, 12) and pollutants from oil-well fires (11–14), exposures that have been associated with increased risk of respiratory illness (15, 16) and increased morbidity (17, 18).

Reports concerning respiratory conditions in troops deploying to the current conflicts in Iraq and Afghanistan began surfacing in 2004 (19, 20). Exposure to environmental conditions (e.g., severe sandstorms, burning feces/trash, smoke from oil-well fires) in these regions was the most frequently documented concern found in medical records of deployed veterans (19). Additionally, respiratory illness was the second most common ailment reported, contributing to decreased operational efficiency and increased hospitalizations in a sample of recent deployers (20). Recent efforts addressing these concerns have included environmental sampling and characterization of ambient air quality in regions of deployment (21, 22), as well as planned epidemiologic studies investigating the potential health impact of particulate matter exposure among deployed personnel (23).

As the current conflicts persist, troops continue to experience multiple and prolonged deployments to regions where a range of unique environmental exposures may

affect respiratory health. To our knowledge, new-onset respiratory symptoms and conditions following deployments to Iraq and Afghanistan have yet to be described using a prospective approach. This study was designed to examine newly reported respiratory conditions in a large population-based military cohort, of whom 23% were deployed to support the conflicts in Iraq and Afghanistan between baseline and follow-up. Respiratory outcome assessments were analyzed by deployment status and by cumulative time deployed, while stratifying by service branch and controlling for military and demographic characteristics and smoking behavior.

MATERIALS AND METHODS

Study population

Participants were from the Millennium Cohort Study, a 21-year longitudinal study launched prior to September 11, 2001, and the start of the wars in Iraq and Afghanistan. The Millennium Cohort Study was designed to investigate long-term health consequences related to military service. Data used for the current study were from the 2001 enrollment, which consisted of randomly selected participants drawn from a sample of all US military service members on active status in October 2000. A detailed description of the methods used has been published elsewhere (24, 25). To ensure adequate power for statistical inferences, personnel with past deployment experience, women, and personnel in the US Reserve and National Guard were oversampled. A total of 77,047 service members provided written informed consent (37% response rate) and completed a baseline questionnaire (July 2001–June 2003), with 55,021 participating in the first 3-year follow-up (June 2004–January 2006) (71% follow-up rate). Previous analyses from foundation studies demonstrated that cohort members well represented the US military, that health prior to enrollment did not influence participation, and that cohort questionnaire data were reliable (25–34).

Data collection

Data on demographic and military characteristics from the Department of Defense Manpower Data Center were linked to each participant and reflected status at the time of baseline enrollment. These data included sex, birth year category (pre-1960, 1960–1969, 1970–1979, 1980 or later), marital status (never married, currently married, no longer married), race/ethnicity, education (high school or less, some college or bachelor's degree, advanced degree), service branch (Army, Air Force, Navy/Coast Guard, Marine Corps), service component (active duty, Reserve/National Guard), military pay grade (enlisted, officer), and occupation (35).

Smoking status for each participant was prospectively assessed using baseline and follow-up data derived from the following questions: ''In the past year, have you used cigarettes?'', ''In your lifetime, have you smoked at least 100 cigarettes?'', and ''Have you ever tried to quit smoking?'' Nonsmokers were defined as persons who had not smoked cigarettes in the past year and had not smoked at least 100 cigarettes in their lifetime. Past smokers were defined as those who reported previously smoking at baseline or who had smoked at least 100 cigarettes in their lifetime and had successfully quit smoking before follow-up. Current or consistent smokers were defined as persons who had smoked at least 100 cigarettes in their lifetime and had not successfully quit smoking or had not tried to quit smoking at baseline or follow-up. Resumed smokers were defined as past smokers at baseline who were current smokers at follow-up, while new smokers were defined as nonsmokers at baseline who were current smokers at follow-up. New smokers and resumed smokers were aggregated because of small sample sizes.

Deployment data were obtained from the Department of Defense Manpower Data Center and included in- and out-of-theater dates for deployments to Iraq and Afghanistan. Cohort members who had deployed for 1 or more days between baseline and follow-up were considered deployers, while those who had never deployed or had deployed after submitting their follow-up questionnaire were identified as nondeployers. Participants who deployed prior to baseline or completed the questionnaire while on deployment were not included in these analyses. Length of deployment for each participant (in days) was based on all deployments from the first deployment occurring after baseline through the last deployment prior to completion of the follow-up questionnaire. Deployment length was categorized into 4 levels: 0 days (nondeployed), 1–180 days, 181–270 days, and >270 days. Cutpoints were established a priori on the basis of standard deployment lengths and the distribution of the data.

Deployment location was examined in a subpopulation of deployed cohort members. Using the Millennium Cohort Study questionnaire, participants were asked, ''Over the past 3 years, did you receive imminent danger pay, hazard duty pay, or combat zone tax exclusion benefits for deployment to any of the regions listed below?'' Cohort members responding ''yes'' were then asked to record up to 5 of the available country and/or sea codes listed, with a corresponding date for each arrival and departure. Deployment location was categorized as exclusively Iraq, with no other deployment locations; exclusively Afghanistan; exclusively Iraq and Afghanistan or other locations involving support for those military efforts (e.g., Bahrain, Oman, Saudi Arabia); exclusively sea-based locations; exclusively other deployment locations (e.g., Turkey, Philippines, Uzbekistan, etc.); and unknown deployment locations. Deployed cohort members who had missing information or did not report receiving imminent danger pay, hazard duty pay, or combat zone tax exclusion benefits for deployment were excluded from these subanalyses.

Outcomes

This study explored 3 new-onset respiratory outcomes: 1) respiratory symptoms (persistent or recurring cough or shortness of breath), 2) chronic bronchitis or emphysema, and 3) asthma. At baseline, participants were asked, ''Has your doctor or other health professional ever told you that

Table 1. Characteristics of Cohort Members by Deployment Status, Millennium Cohort Study, 2001–2006

Characteristic[a]	Deployed[b] (*n* = 10,753)		Nondeployed[b] (*n* = 35,324)	
	No.	%	No.	%
Sex				
Male	8,783	81.7	24,716	70.0
Female	1,970	18.3	10,608	30.0
Birth year				
Pre-1960	1,898	17.6	9,790	27.7
1960–1969	4,454	41.4	14,259	40.4
1970–1979	3,824	35.6	10,001	28.3
1980 or later	577	5.4	1,274	3.6
Marital status				
Currently married	7,055	65.6	23,770	67.3
Never married	3,022	28.1	8,914	25.2
No longer married	676	6.3	2,640	7.5
Race/ethnicity				
White, non-Hispanic	7,637	71.0	25,138	71.2
Black, non-Hispanic	1,166	10.8	4,422	12.5
Hispanic	617	5.8	2,055	5.8
Asian/Pacific Islander	1,078	10.0	2,961	8.4
Other	255	2.4	748	2.1
Education				
High school or less	4,631	43.0	15,096	42.7
Bachelor's degree/some college	5,243	48.8	15,813	44.8
Advanced degree	879	8.2	4,415	12.5
Smoking status[c]				
Nonsmoker	6,088	56.6	20,219	57.3
Past smoker	1,916	17.8	7,713	21.8
Resumed/new smoker	1,152	10.7	2,903	8.2
Consistent smoker	1,597	14.9	4,489	12.7
Service branch				
Army	4,862	45.2	16,863	47.7
Air Force	4,040	37.6	9,921	28.1
Navy/Coast Guard	1,335	12.4	7,085	20.1
Marine Corps	516	4.8	1,455	4.1
Service component				
Active duty	6,597	61.3	18,712	53.0
Reserve/National Guard	4,156	38.7	16,612	47.0
Military pay grade				
Enlisted	7,897	73.4	25,364	71.8
Officer	2,856	26.6	9,960	28.2
Occupational code				
Combat specialist	2,621	24.4	6,648	18.8
Health care	786	7.3	4,633	13.1
Electronic equipment repair	992	9.2	3,237	9.2
Electrical/mechanical equipment repair	1,789	16.6	4,314	12.2
Communications/intelligence	738	6.9	2,487	7.0
Functional support and administration	1,602	14.9	7,967	22.6
Craft worker	378	3.5	997	2.8
Service and supply	1,070	10.0	2,789	7.9
Other technical and allied occupations	267	2.5	887	2.5
Student, trainee, or other	510	4.7	1,365	3.9

[a] Recorded at the time of the baseline questionnaire (July 2001–June 2003). All comparisons were significant ($P < 0.05$) using a chi-square test of association.

[b] Deployment was considered if full deployment occurred between the baseline and follow-up questionnaires. Cohort members deploying after completing their follow-up survey were included with nondeployers in these analyses. Cohort members deploying to the current conflict in Iraq and Afghanistan prior to the baseline survey were removed.

[c] Smoking status was assessed using the participant's responses from both the baseline and follow-up questionnaires.

you have any of the following conditions?'' Possible responses available were chronic bronchitis, emphysema, and asthma (information on chronic obstructive pulmonary disease as a distinct medical diagnosis was not elicited). Chronic bronchitis and emphysema were combined because of low endorsement of these conditions. Participants were also asked, ''During the last 12 months, have you had persistent or recurring problems with any of the following?'' Possible responses available were cough and shortness of breath; time periods defining ''persistent'' and ''recurring'' were not given. At follow-up, participants were given the same questions, but with the time frame ''in the last 3 years,'' rather than over the last 12 months. New-onset respiratory outcomes were defined as those occurring in persons who responded ''yes'' regarding the condition at follow-up without a previous indication at baseline. Cohort members reporting a respiratory outcome on the baseline questionnaire were excluded from the analysis modeling that particular outcome, as were those with missing information on the outcome at baseline or follow-up.

Statistical analyses

Univariate analyses, including chi-square tests, were used to examine unadjusted associations of the study outcomes with deployment, smoking status, and demographic and military characteristics. Separate models were constructed to assess each of the 3 outcomes. Multivariable logistic regression was used to compare the adjusted odds of the newly reported respiratory symptoms or conditions in relation to deployment status while simultaneously adjusting for sex,

Table 2. Characteristics of Cohort Members With and Without New-Onset Respiratory Symptoms, by Deployment Status, Millennium Cohort Study, 2001–2006

Characteristic[a]	Deployed[b] (*n* = 9,210)				Nondeployed[b] (*n* = 29,783)			
	New-Onset Symptoms[c] (*n* = 1,295)		No Symptoms (*n* = 7,915)		New-Onset Symptoms[c] (*n* = 3,038)		No Symptoms (*n* = 26,745)	
	No.	%	No.	%	No.	%	No.	%
Sex								
Male	1,028	79.4	6,501	82.1	2,068	68.1	18,835	70.4
Female	267	20.6	1,414	17.9	970	31.9	7,910	29.6
Birth year								
Pre-1960	223	17.2	1,421	17.9	782	25.7	7,383	27.6
1960–1969	475	36.7	3,363	42.5	1,239	40.8	10,901	40.7
1970–1979	481	37.1	2,761	34.9	892	29.4	7,560	28.3
1980 or later	116	9.0	370	4.7	125	4.1	901	3.4
Marital status								
Currently married	796	61.5	5,253	66.4	2,040	67.2	18,063	67.5
Never married	419	32.3	2,177	27.5	742	24.4	6,742	25.2
No longer married	80	6.2	485	6.1	256	8.4	1,940	7.3
Race/ethnicity								
White, non-Hispanic	863	66.6	5,740	72.5	2,044	67.3	19,395	72.5
Black, non-Hispanic	174	13.4	779	9.9	468	15.4	3,066	11.5
Hispanic	105	8.1	405	5.1	238	7.8	1,414	5.3
Asian/Pacific Islander	112	8.7	831	10.5	204	6.7	2,314	8.6
Other	41	3.2	160	2.0	84	2.8	556	2.1
Education								
High school or less	762	58.8	3,104	39.2	1,644	54.1	10,775	40.3
Bachelor's degree/some college	479	37.0	4,085	51.6	1,191	39.2	12,289	45.9
Advanced degree	54	4.2	726	9.2	203	6.7	3,681	13.8
Smoking status[d]								
Nonsmoker	623	48.1	4,676	59.1	1,517	49.9	15,759	58.9
Past smoker	219	16.9	1,418	17.9	675	22.2	5,788	21.6
Resumed/new smoker	158	12.2	803	10.1	304	10.0	2,114	7.9
Consistent smoker	295	22.8	1,018	12.9	542	17.9	3,084	11.5

Table continues

birth year, marital status, race/ethnicity, education, smoking status, service component, military pay grade, and occupational code. Because smoking may increase the risk for respiratory symptoms or conditions and persons in different service branches are likely to experience different deployment-related exposures, interactions between smoking and deployment and service branch and deployment were examined. Collinearity was assessed using a variation inflation factor greater than 4 to indicate a potential problem (36). Additional models were investigated to assess associations between the 3 outcomes and cumulative deployment length, while adjusting for the same covariates. Analyses were conducted among deployers to investigate deployment location. Adjusted odds ratios and 95% confidence intervals were calculated. All analyses were performed using SAS software, version 9.1.3 (SAS Institute, Inc., Cary, North Carolina).

RESULTS

Of the 77,047 participants who completed a baseline questionnaire, 55,021 completed follow-up questionnaires and were available for longitudinal data analyses. Participants were further excluded if they completed a baseline questionnaire during or after their first deployment ($n = 2,861$), completed their follow-up questionnaire during deployment ($n = 2,472$), had missing covariate information ($n = 1,789$), or had missing information on all respiratory conditions defining the study outcomes at baseline or follow-up ($n = 481$). Cohort members who, at follow-up, reported a diagnosis date for their respiratory outcome that preceded the date of their baseline survey ($n = 1,341$) were also excluded. This resulted in 46,077 participants available for these analyses.

Table 2. Continued

Characteristic[a]	Deployed[b] (*n* = 9,210)				Nondeployed[b] (*n* = 29,783)			
	New-Onset Symptoms[c] (*n* = 1,295)		No Symptoms (*n* = 7,915)		New-Onset Symptoms[c] (*n* = 3,038)		No Symptoms (*n* = 26,745)	
	No.	%	No.	%	No.	%	No.	%
Service branch								
Army	792	61.2	3,287	41.5	1,655	54.5	12,311	46.0
Air Force	313	24.2	3,204	40.5	702	23.1	7,810	29.2
Navy/Coast Guard	121	9.3	1,053	13.3	545	17.9	5,521	20.6
Marine Corps	69	5.3	371	4.7	136	4.5	1,103	4.2
Service component								
Active duty	815	62.9	4,755	60.1	1,727	56.8	13,926	52.1
Reserve/National Guard	480	37.1	3,160	39.9	1,311	43.2	12,819	47.9
Military pay grade								
Enlisted	1,090	84.2	5,564	70.3	2,566	84.5	18,444	69.0
Officer	205	15.8	2,351	29.7	472	15.5	8,301	31.0
Occupational code								
Combat specialist	266	20.5	2,003	25.3	481	15.8	5,258	19.7
Health care	77	5.9	620	7.8	315	10.4	3,681	13.8
Electronic equipment repair	107	8.3	732	9.3	273	9.0	2,503	9.4
Electrical/mechanical equipment repair	224	17.3	1,275	16.1	404	13.3	3,144	11.8
Communications/intelligence	102	7.9	541	6.9	211	6.9	1,855	6.9
Functional support and administration	219	16.9	1,134	14.3	743	24.5	5,908	22.1
Craft worker	51	3.9	279	3.5	97	3.2	736	2.7
Service and supply	160	12.4	734	9.3	312	10.3	1,987	7.4
Other technical and allied occupations	30	2.3	198	2.5	91	3.0	651	2.4
Student, trainee, or other	59	4.6	399	5.0	111	3.6	1,022	3.8

[a] Recorded at the time of the baseline questionnaire (July 2001–June 2003). With the exception of service component among deployers and marital status among nondeployers, all comparisons were significant ($P < 0.05$) using a chi-square test of association.

[b] Deployment was considered if full deployment occurred between the baseline and follow-up questionnaires. Cohort members deploying after completing their follow-up survey were included with nondeployers in these analyses. Cohort members who deployed to Iraq and Afghanistan prior to baseline survey submission were removed.

[c] New-onset symptoms were defined as persistent or recurring cough or shortness of breath reported at follow-up, with no previous report at baseline.

[d] Smoking status was assessed using the participant's responses from both the baseline and follow-up questionnaires.

Characteristics of cohort members by deployment status are presented in Table 1. Nearly one-fourth of the cohort had deployed between submission of their baseline and follow-up questionnaires ($n = 10{,}753$). At follow-up, over 50% of participants ($n = 26{,}307$) were identified as nonsmokers, 21% ($n = 9{,}629$) as past smokers, 13% ($n = 6{,}086$) as consistent smokers, 8% ($n = 3{,}629$) as resumed smokers, and 1% ($n = 426$) as new smokers. When deployed and nondeployed cohort members were compared across demographic and military characteristics, men, those born between 1970 and 1979, Air Force personnel, active-duty personnel, and combat specialists were proportionately overrepresented in the deployed population at baseline.

Table 2 shows the characteristics of cohort participants by deployment status and by newly reported respiratory symptoms. For these analyses, participants who, at baseline, reported persistent or recurring cough or shortness of breath were additionally excluded ($n = 7{,}084$), leaving 38,993 persons available for analysis. Approximately 24% of participants had deployed ($n = 9{,}210$). New-onset respiratory symptoms were reported by 11% of the entire cohort ($n = 4{,}333$). Of persons with new-onset respiratory symptoms, 4% reported new chronic bronchitis or emphysema, 5% reported new asthma, and fewer than 1% reported both. New-onset respiratory symptoms were reported by 14% of 1,295 deployers (cough: $n = 937$; shortness of breath: $n =$

Table 3. Unadjusted and Adjusted Odds of Self-reported New-Onset[a] Respiratory Outcomes in Deployers Compared With Nondeployers, Millennium Cohort Study[b], 2001–2006

Service Branch	Respiratory Symptoms[c]				Chronic Bronchitis or Emphysema				Asthma			
	OR	95% CI	AOR[d]	95% CI	OR	95% CI	AOR[d]	95% CI	OR	95% CI	AOR[d]	95% CI
Army	1.79	1.63, 1.97	1.73	1.57, 1.91	1.13	0.86, 1.48	1.25	0.94, 1.67	0.95	0.70, 1.28	1.06	0.77, 1.44
Air Force	1.09	0.95, 1.25	1.09	0.95, 1.26	0.92	0.59, 1.43	0.93	0.59, 1.47	0.81	0.54, 1.23	1.04	0.68, 1.60
Navy/Coast Guard	1.16	0.95, 1.43	1.06	0.86, 1.32	0.77	0.42, 1.42	0.79	0.42, 1.46	0.88	0.49, 1.59	0.90	0.49, 1.65
Marine Corps	1.51	1.10, 2.06	1.49	1.06, 2.08	0.69	0.20, 2.46	0.94	0.24, 3.75	0.50	0.15, 1.71	0.56	0.15, 1.98

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, odds ratio.

[a] New onset was defined as endorsement of the respective respiratory outcome at follow-up, with no previous report of the condition at baseline.

[b] The total number of participants included in each model varied because of exclusion criteria dependent on each specific respiratory outcome.

[c] New-onset respiratory symptoms were defined as persistent or recurring cough or shortness of breath reported at follow-up, with no previous report at baseline.

[d] Adjusted for deployment status, sex, birth year, marital status, race/ethnicity, education, smoking status, service branch, service component, military rank, and occupation.

606) and 10% of 3,038 nondeployers (cough: $n = 2{,}051$; shortness of breath: $n = 1{,}464$). Deployers who reported new-onset respiratory symptoms were more likely to be male, to have been born in 1970 or later, to have never married, to be consistent smokers, and to be serving in the Army when compared with nondeployers who reported respiratory symptoms. Similar low rates of newly reported chronic bronchitis or emphysema (1% vs. 1% over 3 years (3.3 per 1,000 per year)) and asthma ((1% vs. 1% over 3 years (3.3 per 1,000 per year)) were observed in deployers and nondeployers, respectively.

Smoking status did not significantly modify the relation between deployment and newly reported respiratory symptoms ($P = 0.23$) and was included as a covariate in the regression models. Service branch, however, was a statistically significant effect modifier of deployment and newly reported respiratory symptoms ($P < 0.0001$). Therefore, odds ratios and 95% confidence intervals for each newly reported respiratory outcome were stratified by service branch. Both unadjusted and adjusted odds ratios are presented (Table 3). Statistical adjustment accounted for deployment, smoking status, sex, birth year, marital status, race/ethnicity, education, service component, military rank, and occupation. The study population was comprised of 47% Army ($n = 21{,}725$), 30% Air Force ($n = 13{,}961$), 18% Navy/Coast Guard ($n = 8{,}420$), and 4% Marine Corps ($n = 1{,}971$) service members. Among Army personnel, deployers had 73% increased odds of newly reported respiratory symptoms (adjusted odds ratio (AOR) = 1.73, 95% confidence interval (CI): 1.57, 1.91) compared with nondeployers, after adjustment for smoking status and other covariates. Deployed Marine Corps personnel also had an elevated risk for respiratory symptoms (AOR = 1.49, 95% CI: 1.06, 2.08) when compared with nondeployed Marines. No significant associations between deployment and respiratory symptoms were observed among Air Force or Navy/Coast Guard personnel.

Respiratory symptoms were further examined by modeling cough and shortness of breath separately (data not shown). Findings remained consistent, with significantly elevated odds of cough among Army (AOR = 1.74, 95% CI: 1.56, 1.94) and Marine Corps (AOR = 1.76, 95% CI: 1.22, 2.54) personnel and significantly elevated odds of shortness of breath among Army personnel only (AOR = 1.64, 95% CI: 1.45, 1.86). Adjusted odds ratios for shortness of breath were not significant among Marine Corps personnel (AOR = 0.94, 95% CI: 0.59, 1.50). When assessing new-onset chronic bronchitis/emphysema or asthma, associations with deployment were not significant among any of the service branches (data not shown).

Additional analyses assessing deployment duration were performed. Approximately 13% ($n = 5{,}823$) of all service members had deployed cumulatively between baseline and follow-up for 1–180 days, 5% had deployed for 181–270 days ($n = 2{,}328$), and 6% had deployed for more than 270 days ($n = 2{,}602$). Among Army personnel, deployment length demonstrated a dose-response relation, with increasing odds of respiratory symptoms (for deployment lengths ranging from 1 day to >270 days, AORs were 1.59–1.88; $P < 0.0001$) in comparison with no days of deployment, after adjustment for smoking status and other covariates. Air Force personnel who deployed cumulatively for 181–270 days had 41% increased odds of developing respiratory symptoms (AOR = 1.41, 95% CI: 1.07, 1.86) compared with those who did not deploy. Compared with nondeployed Marine Corps members, a deployment length of 1–180 days was significantly associated with 56% increased odds of respiratory symptoms (AOR = 1.56, 95% CI: 1.04, 2.35), although findings for deployment lengths of 181 days or more were not statistically significant. No further significant associations between deployment length and other respiratory outcomes were observed.

In a subpopulation of deployed cohort members with self-reported information on deployment location ($n = 9{,}861$), 35% ($n = 3{,}474$) reported deployment to Iraq exclusively, 4% ($n = 373$) reported deployment to Afghanistan exclusively, 33% ($n = 3{,}232$) reported deploying to both Iraq and Afghanistan or to other locations in support of those military efforts, 5% ($n = 486$) reported sea-based deployments, 9% ($n = 937$) reported deployment to other locations, and 14% ($n = 1{,}359$) had been deployed to an unknown location. Overall, 14% of deployed participants reported respiratory

symptoms. Of the 6 locations, deployment exclusively to Iraq represented the highest proportion of newly reported respiratory symptoms (18%), followed by deployments exclusively to Afghanistan and to unknown locations (both 14%), deployments to Iraq and Afghanistan or to other countries in support of those efforts (12%), sea-based deployments (9%), and lastly deployments to other locations (8%). Among the examined locations, deployment exclusively to Iraq displayed the largest odds of association with risk of respiratory symptoms (AOR = 2.16, 95% CI: 1.52, 3.07), followed by deployment exclusively to Afghanistan (AOR = 1.87, 95% CI: 1.17, 2.99), deployment to unknown locations (AOR = 1.77, 95% CI: 1.22, 2.59), and deployment to Iraq and Afghanistan or other countries in support of those efforts (AOR = 1.68, 95% CI: 1.18, 2.40). No association was observed between other deployment locations and respiratory symptoms. Chronic bronchitis or emphysema and asthma were not significantly associated with any of the deployment locations examined.

DISCUSSION

Respiratory illnesses were reported to be associated with military deployment to the 1991 Gulf War (1, 3, 6, 37, 38) and are again being reported by deployers to the wars in Iraq and Afghanistan (19, 20). The current results are reassuring in that no increase in reported asthma, chronic bronchitis, or emphysema was noted in the short term. A dose-response relation appeared between cumulative time deployed and risk of respiratory symptoms in Army cohort members but was not seen in Air Force, Marine Corps, or Navy/Coast Guard personnel. These data reinforce findings that deployment is associated with respiratory conditions which may precede the development of chronic pulmonary diseases. Although similar findings were seen after the 1991 Gulf War, it was not possible to determine whether the higher rates of self-reported respiratory illness were due to higher occurrence of new respiratory conditions, higher baseline prevalence, or reporting, selection, or confounding bias. Given the strengths of a prospective study with known baseline information, including data on smoking, the present study found higher rates of respiratory outcomes due to a higher occurrence of persistent and recurring cough among deployed Army and Marine Corps personnel and persistent and recurring shortness of breath among Army personnel, with no increased odds for these respiratory symptoms being seen among Air Force or Navy personnel.

The association between military deployment and long-term respiratory illness has been previously studied among 2,100 1991 Gulf War veterans, of whom approximately half were deployed (39). That study included medical histories, physical examinations, and pulmonary function testing for each participant. Self-reported wheezing and a history of smoking were more frequent among deployed veterans, but no significant difference in physician visits for pulmonary complaints, hospitalization for pulmonary problems, pulmonary function, or the prevalence of emphysema was noted (39). The authors concluded that there was no increased prevalence of clinically significant pulmonary abnormalities 10 years after deployment. Similarly, in a study of Australian Gulf War veterans, though higher prevalences of wheezing, cough, and dyspnea were reported, no differences in pulmonary function testing (spirometry) in relation to deployment were noted (3). These findings and those of the current study suggest that deployment may increase the risk of acute and short-term respiratory conditions. While stress was entertained as a possible mechanism for increased respiratory symptoms, as has been reported in other research (40–45), one might have expected to see increased risk across all service branches for deployers. In the current study, however, we found significantly increased levels of respiratory symptoms among Army and Marine Corps members only. This could reflect additional stress during deployment to which Army and Marine Corps personnel are primarily exposed. In a subanalysis of deployers, Army and Marines Corps members with combat exposure were at increased odds of respiratory symptoms when compared with deployers without combat exposure. Higher stress during deployment among these subpopulations may, in part, explain the findings of the main analysis.

It is unclear how the current findings relate to a previous report of eosinophilic pneumonia diagnosed in a very small number of servicemen in theater, with cases being severe and occasionally fatal (46). The mechanism of eosinophilic pneumonia in these cases has not been clearly determined, but a link with new-onset smoking in theater was suggested. Such unusual diagnoses in deployed cohort members may represent only the far end of a wider spectrum of respiratory conditions that is also characterized by a higher frequency of chronic respiratory symptoms among deployers, which we report in the current study. A recent report noted that since monitoring for deployment-related severe acute pneumonia (including eosinophilic pneumonia) began in 2004, only a few cases per month have been found (47).

This study had several limitations. The current analyses used self-reported data from survey questionnaires. Nonetheless, the comprehensive survey instruments use validated questions and are administered consistently at 3-year intervals. However, clinical examinations for confirmation of self-reported symptoms and conditions were not conducted, and respiratory outcomes included in the study may not equate to a physician's diagnosis and may not reflect the full spectrum of respiratory outcomes. Additionally, history of medical treatment for respiratory illness during the follow-up periods was not available. The differential diagnoses list is long for patients with respiratory conditions, which include symptoms and illnesses that may result from a large collection of etiologic agents spanning broad categories of infections (viral and bacterial) and irritants (gaseous and particulate), as well as other comorbid health conditions. Although our study lacked the precision to link respiratory pathology with specific exposures, it more clearly defined the complicated relation between deployment and respiratory health outcomes, particularly in light of the elevated risk among persons with land-based deployments. However, exposure data beyond service and deployment dates and country location were not available. Finally, the short period of data collection (2.7 years, on average) may only have allowed identification of acute conditions and may have missed chronic conditions that develop over a longer

time period. Further follow-up studies will better identify the relation between deployment-related exposures and long-term respiratory conditions and possible intervention points for diminishing acute, intermediate, and long-term adverse outcomes. Efforts by the Army's Center for Health Promotion and Preventive Medicine include evaluating changes in health outcomes potentially associated with higher cumulative levels of particulate matter exposure among deployers (23).

This study also had several unique strengths. Its population-based, prospective cohort design allowed for baseline and follow-up assessment of the same persons from all service branches and components (active duty, Reserve, and National Guard), including those no longer in military service. Additional strengths included random sampling for identification of study participants; data on the incidence, as opposed to the prevalence, of health outcomes; large sample sizes that provided strong statistical power for assessing chronic and latent disease; the ability to control for multiple confounders, including smoking; and the ability to conduct long-term follow-up studies in the future using cohort analytic methods.

In summary, inconsistency in risk for new-onset respiratory conditions and cumulative exposure time by service branch strongly suggests specific exposures, rather than deployment in general, as determinants of postdeployment respiratory illness. The significant associations with deployment location that were more strongly noted among persons deployed exclusively to Iraq raise concerns over possible environmental exposures and may deserve further study. A recent environmental sampling study revealed geologic dusts, smoke from burn pits, and heavy metal condensates, including lead and arsenic, as the 3 main types of air pollutants in 15 locations of deployment in the Middle East that included areas in Iraq (21). The findings of statistical significance in Army and Marine Corps deployers, more than in Air Force and Navy deployers, also suggest that exposures related to ground combat, including stress, may be more influential in the development of postdeployment respiratory symptoms. Finally, in future prospective analyses, investigators will be able to determine whether symptoms resolve or progress over time and whether long-latency respiratory diagnoses, such as chronic obstructive pulmonary disease, become more significantly associated with deployment-related exposures. The need for such long-term evaluations highlights the value of the Millennium Cohort Study, which can prospectively address the challenging questions of long-term health consequences associated with occupational and environmental exposures.

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14. ABSTRACT

Of the 46 077 participants, approximately 23% had deployed to Iraq or Afghanistan between baseline and follow-up. The proportion of newly reported respiratory outcomes in deployers versus nondeployers were as follows: respiratory symptoms (14.2 vs 10.3%), chronic bronchitis or emphysema (1.1 vs 1.1%), asthma (1.0 vs 1.2%), and any respiratory condition (14.4 vs 10.5%). Symptoms and conditions were associated with deployment in both Army and Marine Corps members, with no statistical increase found in Air Force and Navy members. Deployment lengths were not linearly associated with increased symptom reporting. While it is reassuring to note no increase in newly reported asthma, chronic bronchitis, or emphysema, increases in newly reported respiratory symptoms in Army and Marine Corps deployers, independent of smoking behavior, demographic, and military characteristics, are of concern.

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